2003 LARP Collaboration Meeting

Quad R&D Issues and Options

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September 16-18, Danfords on the Sound, NY

Design options

Two fundamental design approaches to 2nd generation LHC IRs:

1. **single-bore inner triplet design with a maximum aperture;**
2. **dipole-first designs with double-bore quadrupoles with a maximum aperture at a minimum beam separation.**

Quadrupole parameters:

>90 mm coil aperture;

205 T/m nominal gradient and 20% quench margin;

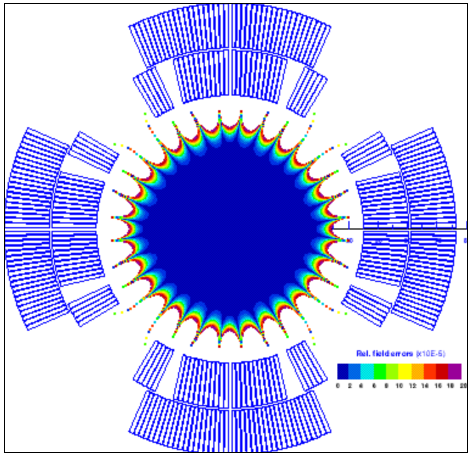
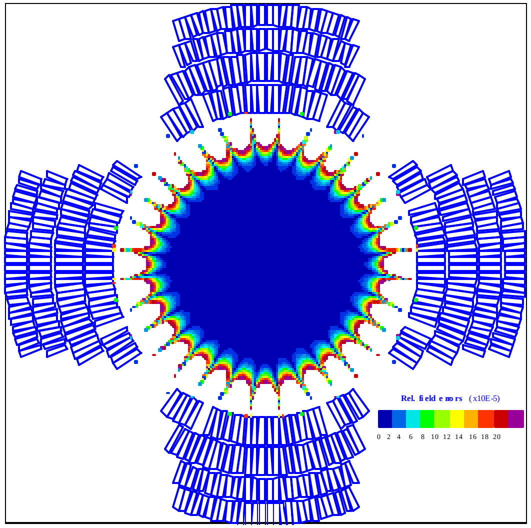
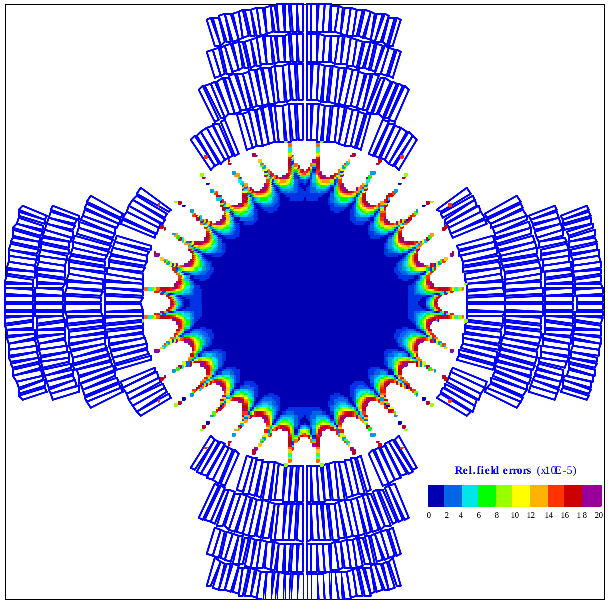
1.9 K (4.5 K) operating temperature.

R&D questions

- Optimum design for large-aperture quadrupoles?
- Optimum aperture?
- Optimum bore separation for double-bore magnets?
- Field quality in single and double bore magnets?
- Temperature margin and quench protection?
- Mechanical support and coils prestress?
- Cryogenics?

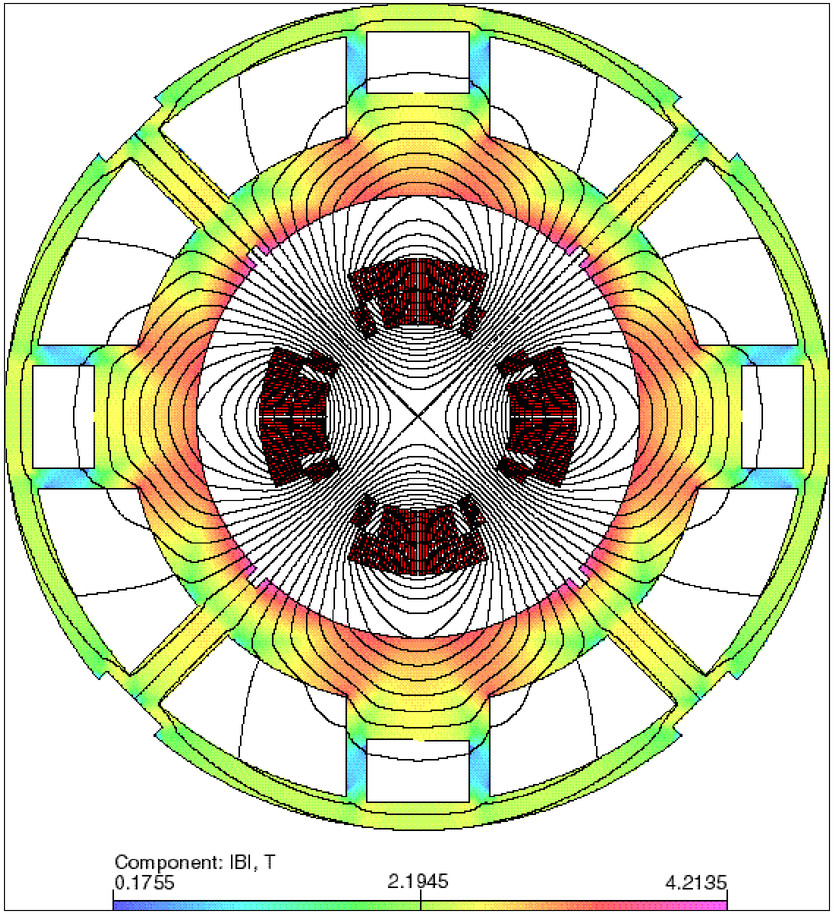
These questions have to be addressed during conceptual design studies and model magnet R&D.

Quadrupole coil designs

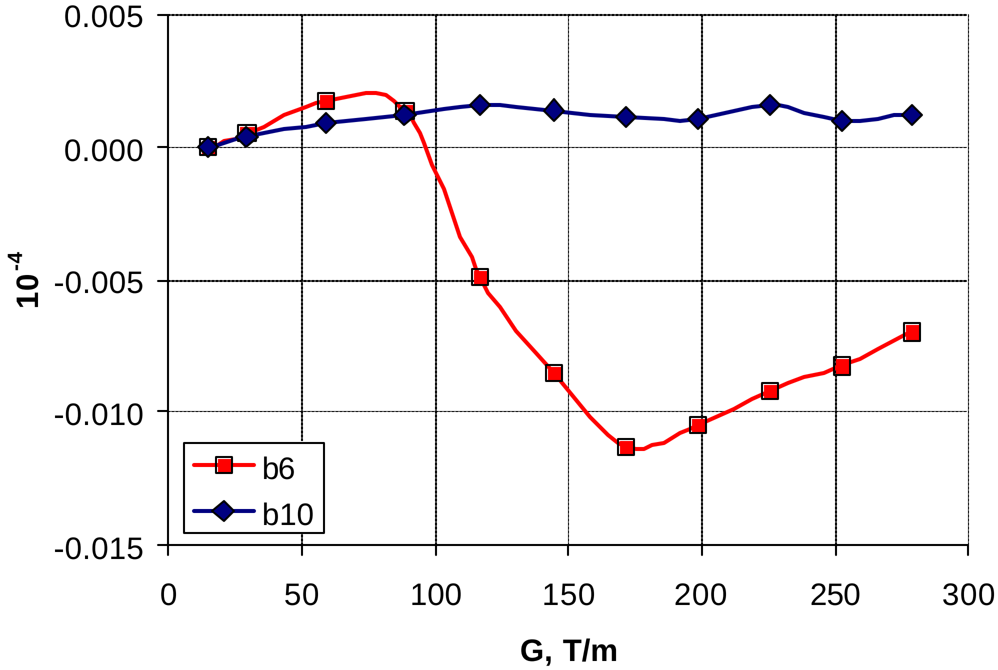
90-mm	100-mm	110-mm
		

	90-mm	100-mm	110-mm
N_{turns} =	144	228	248
S_{coil}, cm^2 =	48.1	59.3	84.9

Quadrupole magnet yoke with cooling holes

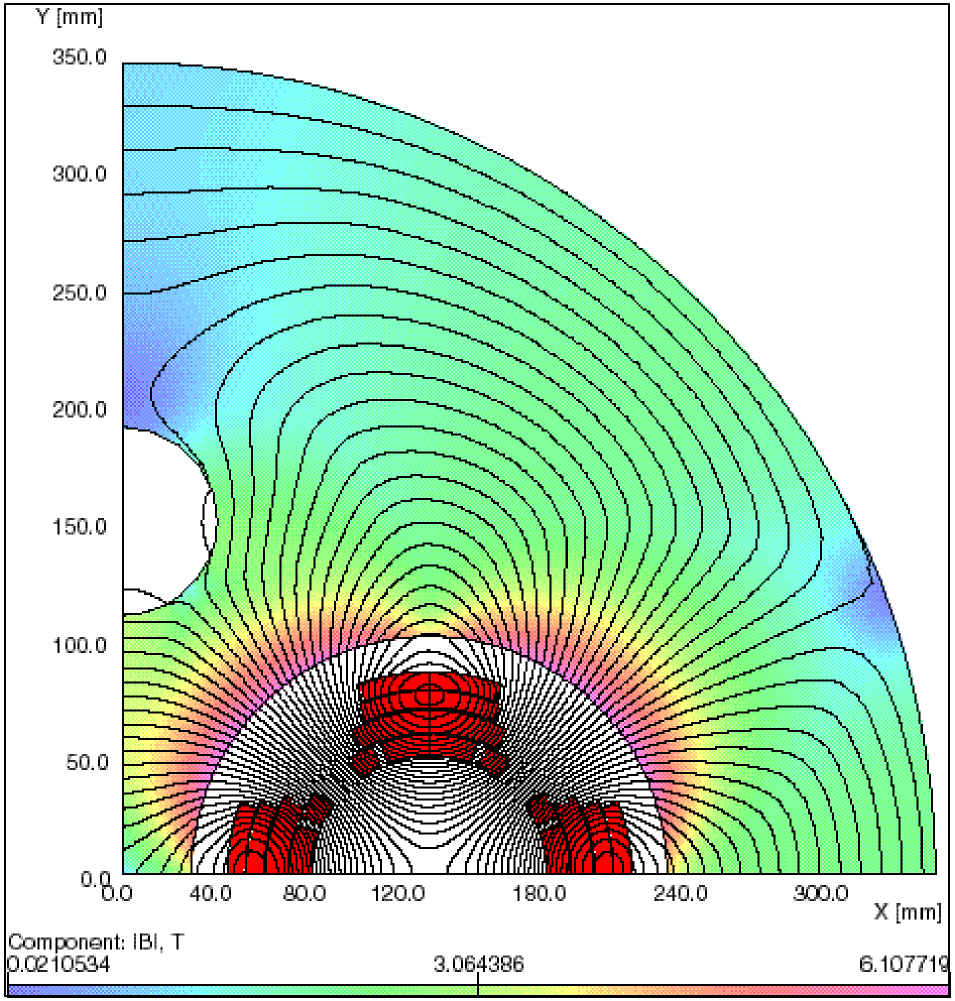


R_{ref} = 17mm



Yoke saturation can be controlled by hole optimization

Double-bore magnet

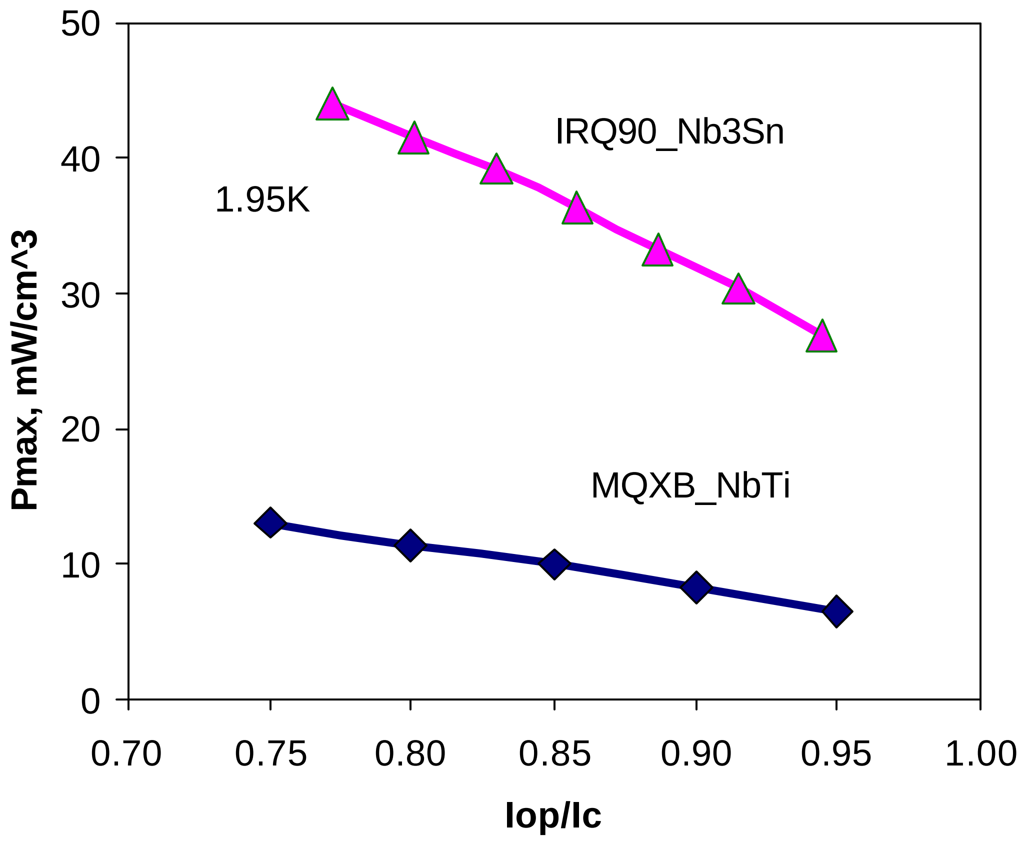


Field errors can be < 10^{-4} with bore separation > 250 mm and yoke OD > 700 mm

Bore separation and yoke size can be reduced in a "warm" yoke design,

but the coils would have to have considerable left-right asymmetry and a large number of wedges

Thermal analysis



The Nb_3Sn magnet designed with 20 % quench margin can take 40 mW/cm^3 of peak power dissipation in the midplane turns.

Quench protection

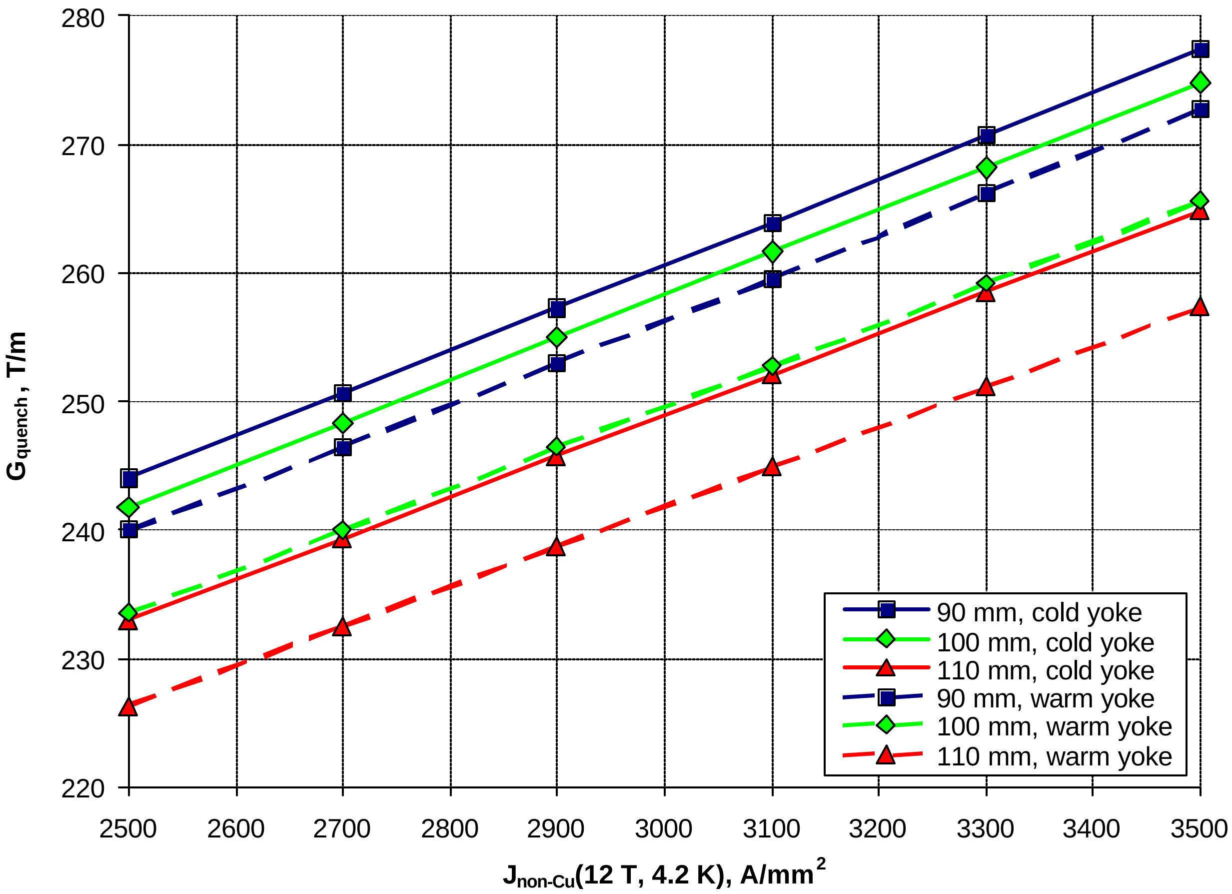
The inductance and stored energy the 110-90 mm quads and calculated T_{hs} and T_{blk} are reported below for F_{qh} of 50% and 25%.

The acceptable T_{max} for accelerator magnets is 300-400 K and F_{qh}<50%.

Even for F_{qh}=25% T_{max} is within 315-335 K. With F_{qh}=50% T_{max} does not exceed 250 K.

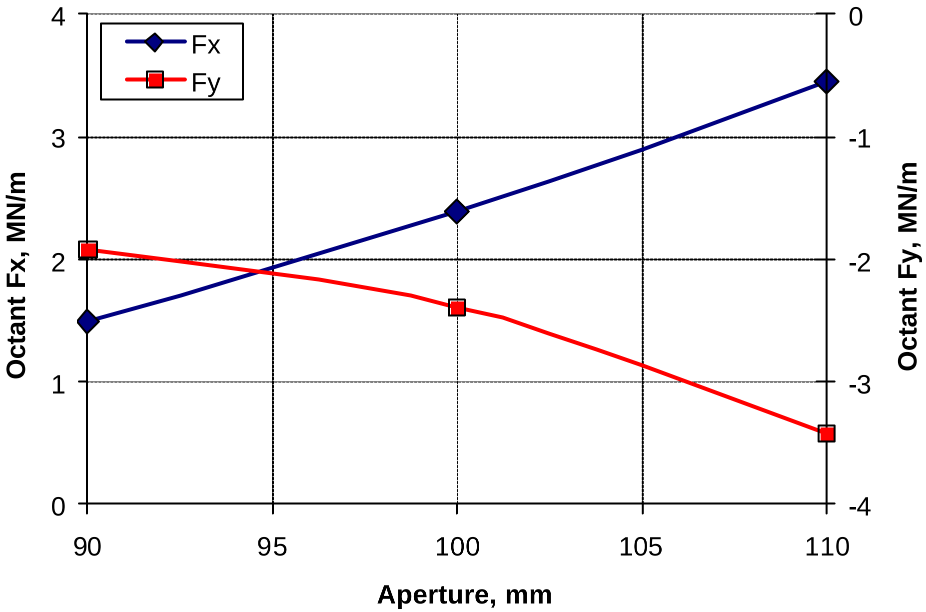
Parameter		Aperture		
		110 mm	100 mm	90 mm
L, mH/m		17.46	14.71	4.86
W(205 T/m), kJ/m		1181	703	468
T_{hs}, K	F_{qh}=50%	230	225	230
	F_{qh}=25%	335	320	315
T_{blk}, K	F_{qh}=50%	150	140	127
	F_{qh}=25%	220	200	180

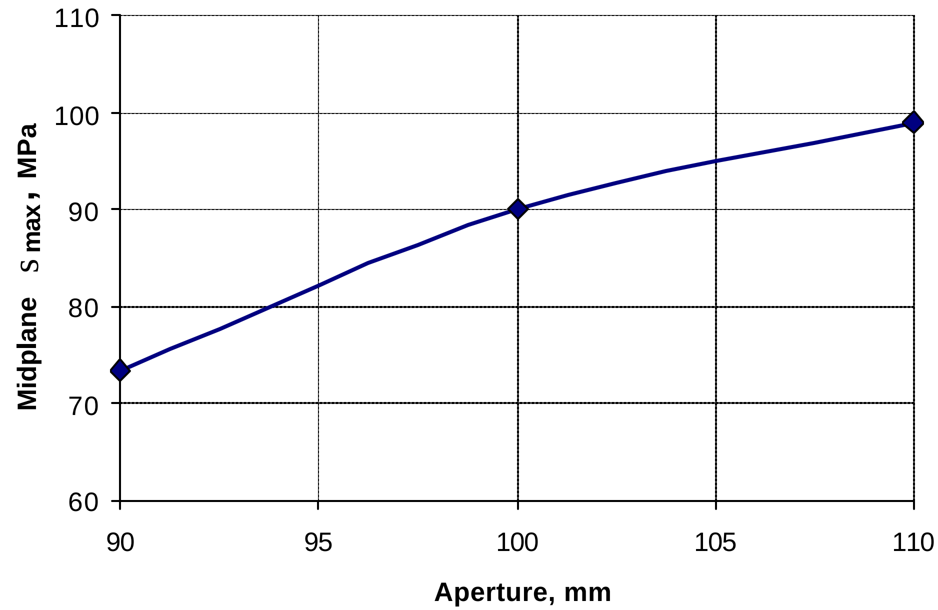
“Warm” vs. “cold” yoke design



Maximum gradient in a warm yoke design drops by only 3-4 %

Forces and stresses





Stress in the 110 mm quad coil reaches 100 MPa. The coil needs to be pre-stressed during assembly to the level where irreversible superconductor degradation occurs.

A possibility of bladder technique can be explored to reduce stresses.

Summary

The studies show that 90-110-mm aperture quadrupole magnets using Nb_3Sn strands, expected to be available in the next few years, can provide the maximum field gradient of 250-260 T/m with an acceptable field quality.

The cold yoke design have large holes for cooling that can be optimized for good field quality.

A warm yoke can be an interesting option for a single-bore magnet but rather challenging for double-bore design.

Peak temperatures during quench are acceptable for all the designs in spite of large stored energies.

The mechanical structure needs to be carefully optimized during R&D.